Active Project (2014 - 2016)

# Iodine Hall Thruster Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)

## ANTICIPATED BENEFITS

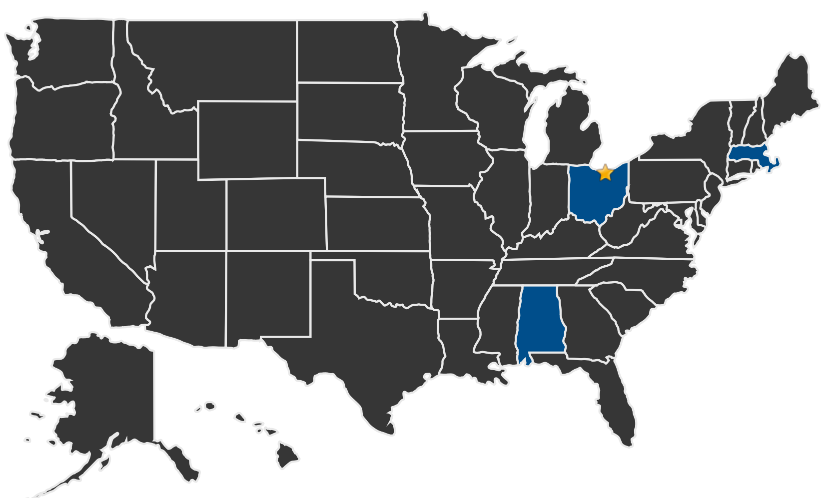
**To other government agencies:**

The capability for high ΔV maneuvers on SmallSats may enable low cost constellation deployment, orbit tranfer to higher value orbits and provide station keeping for either formation flying or drag makeup. These capabilities enable geocentric applications including low-cost access to high value orbits, presistant coverage constellations, and required de-orbit capability.

## DETAILED DESCRIPTION

A Iodine Hall thruster electric propulsion system provides high delta-V performance which will enable missions previously unachievable with small spacecraft. The new propulsion system will take advantage of the ~2.4X improved propellant density to extend mission operations in low earth orbit and enable deep space planetary science missions.

## U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

**Lead Center:** Glenn Research Center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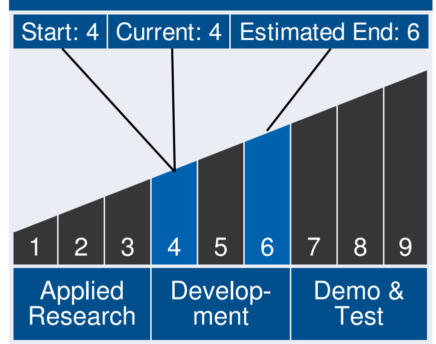
Technology Maturity



**Other Organizations Performing Work:**

- Busek Company, Inc. (Natick, MA)

## PROJECT LIBRARY

### Conference Papers

- Mission and System Advantages of Iodine Hall Thrusters
    - (http://ntrs.nasa.gov/search.jsp?R=20140012585)
- The iodine Satellite (iSAT) Hall Thruster Demonstration Mission Concept and Development
    - (http://ntrs.nasa.gov/search.jsp?R=20140012578)

Realized Benefits

2 Conference Papers

## Management Team

**Program Executive:**

- Lanetra Tate

**Program Manager:**

- Mary Wusk

**Project Manager:**

- Timothy Smith

**Principal Investigator:**

- Charles Taylor

## Technology Areas

**Primary Technology Area:**
In-Space Propulsion Technologies (TA 2)
└ Non-Chemical Propulsion (TA 2.2)
  └ Electric Propulsion (TA 2.2.1)
    └ Hall Thrusters (TA 2.2.1.2)
    └ Hall Thrusters (TA 2.2.1.2)

## DETAILS FOR TECHNOLOGY 1

### Technology Title

Iodine Hall thruster propulsion system

### Technology Description

This technology is categorized as a hardware subsystem for ground scientific research or analysis

The thruster is 600W  derivative of the Busek Co., Inc. BHT-200 xenon-fed flight thruster. The BHT-200 is the first American Hall effect thruster flown in space, launched in 2006 as part of the TacSat-2 project. The BHT-200 was first tested with iodine under an Air Force SBIR and presented in 2011.3 The performance results indicate the thruster performs at similar efficiencies or slightly higher efficiencies as with xenon propellant, but with slightly higher thrust-to-power and reduced plume divergence.

Busek and NASA GRC have been investigating iodine cathode options for long life capabilities, primarily lanthinum hexaboride (LaB6). Additionally, NASA and Busek have been investigating the C12A7 electride cathode as a heaterless option.7 Colorado State University (CSU) has demonstrated 50 hours of operation on a single insert, including testing on iodine, and their results did not show any signs of cathode degradation. NASA purchased multiple cathodes from CSU for additional testing with iodine. Specifically, NASA GRC has modified one cathode with diagnostics for ignition

While the thruster is usually emphasized for technology development and mission benefits, the power processing unit (PPU) typically represents the highest cost and schedule risk item at the system level. Even more so than the thruster, the 600W PPU has benefitted from significant investments through the both NASA and AF SBIR programs. A key programmatic advantage for iodine Hall thrusters is that the thruster requires almost exactly the same voltage and current as the xenon model, permitting the direct use of PPUs that have already been designed and qualified for conventional xenon Hall thrusters. Unfortunately, the early xenon feed system control and Digital Control Interface Unit (DCIU) functionality typically included in the PPU was not initially applicable to a iodine-fed system.  The compact PPU effort reduces the mass and volume of the PPU by almost 80% and 90% respectively

The iodine feed system is one of the main drivers in the iSAT system development since it contains much of the propulsion system risk. Unlike xenon, iodine is a solid under ambient conditions. The entire propellant management system operates at very low pressure, much less than 1 atmosphere. This has significant advantages at the spacecraft and mission level, but presents challenges for the feed system. Additionally, iodine is highly reactive with iron and expected to be reactive with a range of typical flight feed system materials.

The iodine in the propellant feed system starts as a solid in the propellant reservoir. The propellant is heated to achieve the desired pressure in the tank through sublimation (typically under 100 torr). The iodine vapor flows first through a latch valve and then through a proportional flow control valve (PFCV) which is an adjustable orifice that offers precise, fast response flow metering and control. Downstream of the PFCV, the flow is proportionally split to deliver the proper amount of iodine vapor to both the thruster and cathode. Special attention is required to minimize pressure drops in the line, which in addition to maintaining temperatures elevated above those in the propellant reservoir serves to minimize the danger of iodine deposition in the feed lines

**Capabilities Provided**

A range of mission studies have been completed to identify mission level advantages using iodine as the primary propellant. In addition to iodine based missions for commercial, military, human and robotic exploration, multiple concepts have been developed for a low-cost high value technology demonstration mission. The mission benefits primarily result from two enabling features of iodine, the increased propellant density and low operating pressure Multiple studies have been performed with the NASA GRC COMPASS team and the NASA MSFC Advanced Concepts Office to assess the viability of iodine SmallSats to delivery high value science for low-cost. Iodine can help overcome one of the key limitations to small satellite exploration; the lack of primary propulsion. Additional challenges for SmallSats is due to limited resources available: power, mass, and volume. The capability for high $\Delta V$ maneuvers on SmallSats may enable low cost constellation deployment, orbit tranfer to higher value orbits and provide station keeping for either formation flying or drag makeup. These capabilities enable geocentric applications including low-cost access to high value orbits, presistant coverage constellations, and required de-orbit capability.

**Potential Applications**

The market has established xenon fueled electric propulison systems in the 1-9kW power range. Here there is limited justification to supplant incumbents with lower maturity technology. However, both the very small and very large satellite markets have limitations that may be overcome through the implementation of iodine. Small thrusters may be ideal for CubeSats or other small spacecraft where volume is at a premium. Large thrusters and clusters with high throughput requirements can offer system packaging and propellant storage. Also, higher power systems with high flow rates may offer ground test advantages over non-condensable propellants, and therefore mission margin reduction and flight performance risk reduction. Large system applications may include large orbital tugs and human exploration missions.

## Performance Metrics

| Metric | Unit | Quantity |
| --- | --- | --- |
| Specific Impulse | sec | 1600 |
| Density Specific Impulse | g-sec/cu. cm | 7840 |
| Propulsion system life | hours | 15000 |